Standard Data Exchanges for Distribution System Management

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1 Executive Summary

Databases and software tools for electric power distribution systems have not been integrated, and this leads to extra costs and restrictions imposed on utilities and other stakeholders. For example, distributed resource integration studies and modern grid technology assessments are more difficult and costly. New vendors face high market entry barriers, because it's necessary to interface with large and customized data systems at each potential utility customer. This project promotes data and software tool integration, through a set of data translators based on a common object model. The common object model is a harmonized version of two standards:

1. The International Electrotechnical Commission's Common Information Model, with Distribution system extensions
2. The National Rural Electric Cooperative Association's MultiSpeak initiative.

The data translators are delivered as open-source software, using appropriate Web software technologies. The parties who benefit include electric utilities (and their ratepayers), researchers at government laboratories and universities, small software companies wishing to enter the electric utility market, and parties wishing to interconnect distributed generation to a utility system.

Although the Department of Energy chose not to fund this project in Phase II, EnerNex will continue development efforts through business opportunities identified with electric utilities and modern grid initiatives during Phase I. The data translators will be further developed as EnerNex conducts Phase II work under a different SBIR grant, number DE-FG02-06ER84647, "Distribution System State Estimation". That project requires interfacing a university-developed software algorithm to an actual utility system, and the data translators are a critical enabling technology to complete that project.

2 Project Description

The project's goal was to provide data exchange tools for electric power distribution systems. Databases and software tools in this area have not been integrated. Users must contend with data formats and software interfaces that are often proprietary, incompatible, and overlapping. This data integration problem leads to several adverse impacts:

1. Excessive burden of database maintenance – the utility has trouble conducting operations, design, planning, and general asset management at a reasonable cost.
2. Integration of measurements with engineering analysis – system models, loads, and system state information are difficult to update with actual measurements, which limits the usefulness of software outputs.
3. Barriers to integration of Distributed Energy Resources (DER) – the utility has trouble completing interconnection studies within a reasonable time frame.
4. New algorithms do not get into the marketplace – many good ideas for system operation and optimization come from universities, government laboratories, or small companies. Utilities have trouble even trying these ideas, because it is difficult to integrate new software modules into existing systems.

Some commercial software or database vendors provide integration platforms, but these are proprietary and expose the utility to risks associated with vendor lock-in and long-term support costs. Many software vendors have a set of data importers, but fewer have data exporters. Some (but not all) vendors have seen a conflict between their business interests and the principle of interoperability. On the other hand, when a single vendor attempts to define a common data format or software interface, the motivation could be to cement a dominant position in the marketplace. Therefore, it is vital that several vendors be involved in standardization.

The Department of Energy requested data conversion tools between "all" open and proprietary data formats. The only sensible way to approach this is by defining a common object model as the target, with one interface module between that common model and each foreign format. For example, if there are six foreign formats to support, then six interface modules must be developed. Without a common object model, each pair-wise interface might have to be implemented separately, and that would mean up to 15 different modules to develop.

The International Electrotechnical Commission (IEC) object model, as defined in three evolving standards [1], provides one prominent object model:

1. Standard 61850 – substation automation
2. Standard 61968 – distribution system common information model (DCIM)
3. Standard 61970 – common information model (CIM)

The National Rural Electric Cooperative's MultiSpeak Initiative [2], provides another prominent object model. The MultiSpeak effort is actually further along than the IEC standard. It has released version 3, and many software vendors are supporting MultiSpeak interfaces.

The CIM, DCIM, and MultiSpeak are all implemented in Extensible Markup Language (XML) and they embody the principle of "standard names for standard things". They don't yet include all necessary information, especially for simulation models, but the IEEE standard radial test feeders have been described successfully in a draft version of DCIM [3]. The standards do include real-time electrical parameter measurements like voltage and current, offering the possibility of a direct, two-way interface between Engineering Analysis (EA) software and Intelligent Electronic Devices (IEDs) in the field.

With XML implementations underlying the DCIM and MultiSpeak, the Extensible Stylesheet Transformation language (XSLT) offers an efficient and standardized method of converting another data format to the object model. EnerNex has used this method to interface MultiSpeak circuit models to a customized EA data format [4]. XSLT can also be used for translating tabular text files, typically comma-delimited (CSV) or tab-delimited, into the XML-based object model. Newer versions of office productivity tools also have XML export features, which are then amenable to XSLT-based conversion to the object model. Although XSLT has a learning curve, it has become a standard Web development tool and that reduces the training burden.

The data converters will be delivered as open-source software, which allows for widespread usage and long-term support. The Department of Energy has expressed a strong interest in open-source software, and because EnerNex is not a commercial software vendor, there is no conflict between open-source and EnerNex's business interest.

3 Anticipated Public Benefits

Commercial vendors, university researchers, electric utility engineers, and other interested parties will expand and maintain the data converters, with no further cost to the government. For example, a commercial software vendor might write the initial version of a two-way translation module between their product and the common object model. After subsequent releases of the IEC standards, the MultiSpeak standards, or the commercial product, that vendor would update "their" translation module. An electric utility or university researcher can also write their own translation modules for in-house custom software or databases, or to support research into new algorithms. Existing modules will serve as examples for those maintaining or extending the system.

The Federal Government especially benefits by making the results readily available through the open source mechanism. It will not be necessary for a user to choose this product over another one, nor does it displace any existing products.

Technical benefits include the following:

1. Utilities will be able to use the best tool for the job. Several tasks or functions could be performed with different point tools, each of which is easier to fit within the overall work flow or asset management system.
2. Utilities will be able to integrate engineering analysis and planning with all other functions.
3. The accuracy of planning, optimization, and forecasting functions will improve through tighter integration with measurements (device settings, device states, voltage, current, etc.)

Economic benefits for electric utilities, and by extension their ratepayers, include the following:

1. Reduced training costs.
2. Reduced database maintenance costs.

Societal benefits include the following:

1. Electric power distribution systems could be designed and operated more economically and reliably.
2. Distributed resources, including renewable sources, will have easier integration.

Parties who benefit include the following:

1. Electric utilities will benefit, by reducing their training time and data maintenance efforts, and also through a broader choice of software tools and systems.
2. DER applicants will benefit through more access to utility data. Integration studies should be quicker and cheaper.
3. New software vendors will benefit through lower market entry barriers. This also applies to university researchers.
4. Anyone working on modern grid research will find it easier to conduct economic or technical simulations of new concepts on actual utility systems.

Many of the government's national laboratories have become involved with various modern grid initiatives, as listed in Section 7 of this report. The government laboratories will benefit from this project by enabling the assessment of new technologies or systems applied to the grid. These assessments often require custom software, which may be difficult or expensive to integrate with actual utility databases. A set of standardized data conversion tools will enable such assessments to be performed at a reasonable cost.

4 Accomplishments vs. Goals

The original plan was to build the common object model around the international IEC and CIM standards. During this project, the focus was changed, by necessity, to use MultiSpeak as the basis for a common object model, while still working to harmonize the IEC and MultiSpeak efforts. This change made two of the six proposed tasks obsolete, as discussed in Section 5 of this report. Instead, efforts and progress were made in other areas.

Figure 1 shows our updated concept of a data integration system, built around a harmonized MultiSpeak / IEC object model for distribution systems. After attending one meeting of IEC TC 57 / WG14, it became obvious that publication of a useful version of this standard is many years away. By contrast, the MultiSpeak Initiative has taken a more pragmatic, if less rigorous approach. MultiSpeak is currently in version 3; it has support from a few dozen vendors, and is used by perhaps 100 utilities. Although MultiSpeak makes a point of its emphasis on rural electric cooperatives, we believe the data requirements of much larger utilities are quite similar, at least for the distribution system.

Therefore, we have chosen MultiSpeak as the basic format for data exchanges. As noted in Figure 1, MultiSpeak already supports data transfer, through Web services, between Supervisory Control and Data Acquisition (SCADA) systems and other software functions. Although it's not complete for our purposes, the development process for MultiSpeak is more nimble and responsive than the one for IEC. At present, only one engineering analysis vendor is involved with MultiSpeak. That probably explains most of the gaps we found in MultiSpeak, because engineering analysis vendors have not been exchanging model data through MultiSpeak yet. However, EnerNex is able to contribute to MultiSpeak, and will work to harmonize the MultiSpeak and IEC standards.

During the project, EnerNex was involved in the National Energy Technology Laboratory (NETL) Modern Grid Initiative, and similar projects. This experience made clear that government laboratories and other researchers need a set of standardized data conversion tools for electric power distribution systems.

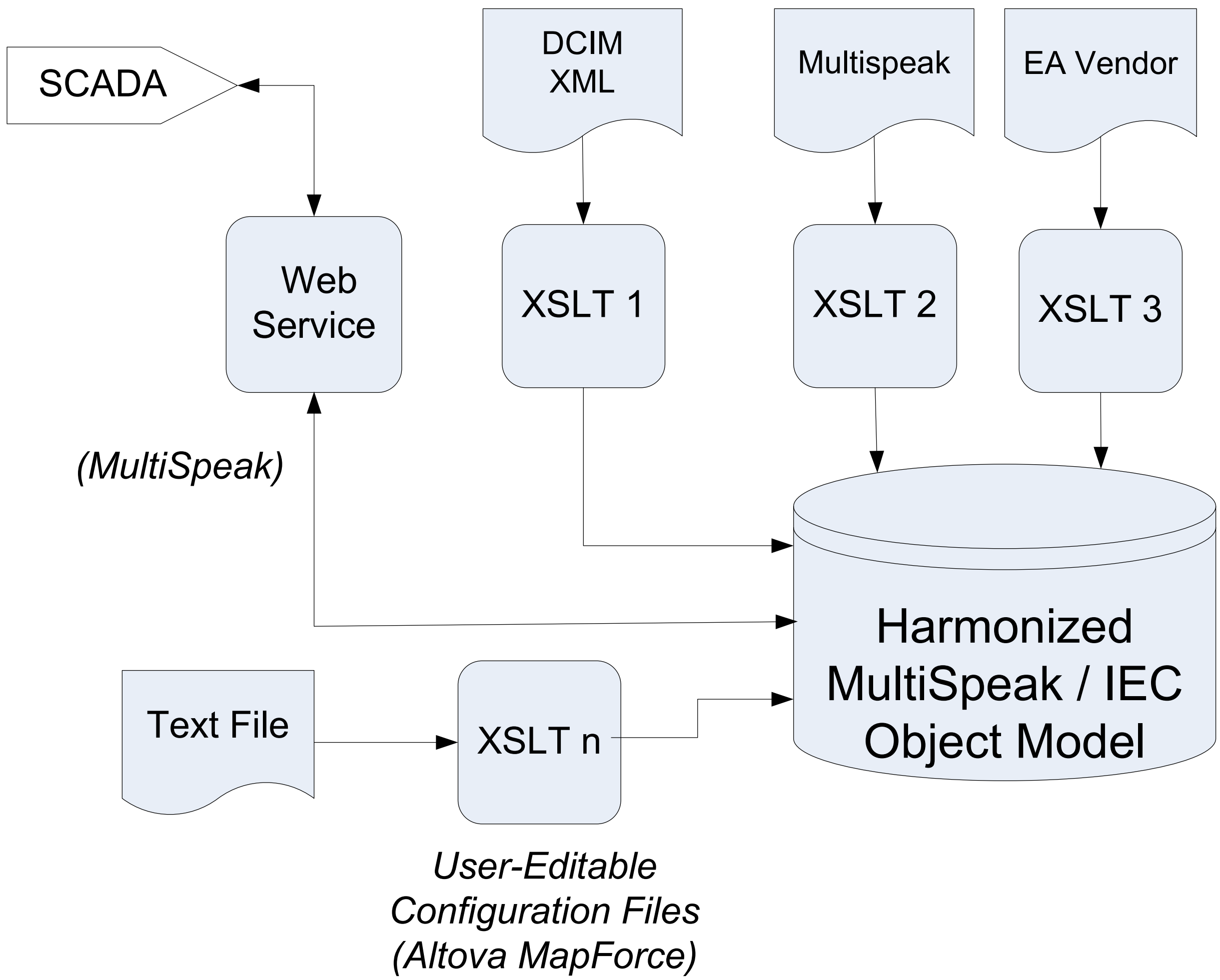

Figure 1 - Modular data interfaces to a common object model for distribution systems

5 Summary of Activity

The detailed work plan comprised six technical tasks:

1. Express the IEEE Radial Test Feeders in DCIM
2. Set Up an Open Source Platform
3. Implement a 2-Way MultiSpeak Converter in XSLT
4. Implement a 2-Way ASPEN *DistriView* Converter in XSLT
5. Implement a 2-Way ASPEN *Line Constants* Converter in XSLT
6. Specify Custom Data Interfaces for Subsequent Work

The IEEE Radial Test Feeders in Task 1 provide a good benchmark for assessing the suitability of a proposed object model for distribution systems. An object model designed for transmission systems would likely not be able to completely describe these test feeders.

ASPEN is a prominent software vendor for transmission system analysis, and two of their distribution software products were chosen for testing in Tasks 4 and 5. One important reason is that ASPEN, unlike most other software vendors, supports translation of their data files to other formats. Another reason is that EnerNex has a favorable business relationship with ASPEN.

For Task 1, we obtained pseudo-DCIM representations for most of the IEEE test feeders from the author of [3]. The qualifier "pseudo" applies because not all of the recommendations from [3] appear in the present DCIM [1], which was disappointing. An expanded IEEE test feeder, with two wind turbine generators, was implemented in pseudo-MultiSpeak during this project [5].

For Task 2, an open source project called *NexPower* was initiated on sourceforge.net [6]. The development is being conducted as an open source project, with the Lesser Gnu Public License (LGPL). The LGPL allows for commercial re-use of the code, so that software vendors could enhance or maintain data translation modules, without fear of "contaminating" their own products through the full GPL terms. The code will be exclusively XSLT, C, or C++, and will run on both Windows and Linux platforms. This general approach improves the code quality and ensures long-term support, by encouraging tests and contributions from the open-source community. As the primary developer, EnerNex is the gatekeeper for modifications to the open-source code base. There is no conflict with EnerNex's business interest in adopting the open source model.

For Tasks 3 and 5, the principal investigator joined the MultiSpeak Initiative's technical committee, and the IEC TC 57 / WG 14 producing IEC Standard 61968, "System Interfaces for Distribution Management". It was found that DCIM is not yet ready to serve as the common data exchange format; MultiSpeak is a better choice right now. Therefore, no explicit MultiSpeak translator was developed for Task 3.

The proper object model approach will be to harmonize MultiSpeak and DCIM. This obsoletes Task 3 as it was defined in our Phase I proposal. This process is described in two technical papers by the principal investigator [7, 8]. In summary, the MultiSpeak data schema was expanded in [7] to support line parameter calculations, using the equations as "use cases". The MultiSpeak and DCIM schemas were used in [8] to solve a neutral-earth voltage test case. The neutral-earth voltage, sometimes referred to as "stray voltage", is a topic of much current interest in distribution systems. It's also a demanding test case for both calculations and supporting data requirements. These two papers document the result of a modified Task 3 effort, along with Task 5 on line parameter calculations.

For Task 4, data translators for the ASPEN *OneLiner* and *DistriView* products have been implemented, along with netlist outputs for the *Alternative Transients Program* (ATP) and EnerNex's *NexHarm* harmonics analysis program (which uses a published input format [9]). During the project, these translators have been used to efficiently conduct harmonic and electromagnetic transient studies for ISO New England, Northeast Utilities, National Grid, American Transmission Company, PacifiCorp, and NSTAR Electric. However, in testing *DistriView* on the IEEE radial test feeders, for an IEEE panel session, some technical issues were found in that software product [10]. Its genesis from a transmission software product is very evident. This further illustrates the need for open data formats and new analysis tools – no software vendor can address all of the needs.

For Task 6, we identified and tested Altova *MapForce*, from their popular suite of XML tools, as a convenient means for translating text files to a common XML-based format. We also found that existing MultiSpeak interfaces should be used for SCADA and other interfaces to the common data format. Several of these have already been defined as Web Services.

6 Products Developed

Two IEEE conference papers were written and presented [7, 8]. These describe line parameter and neutral-earth voltage calculations from a common data format. They are available on-line through the IEEE Xplore system.

An open-source development project was created at http://sourceforge.net/projects/nexpower/. This Web site is the repository for all data and software tools developed from this project, and related subsequent work.

The principal investigator joined the MultiSpeak Initiative [2] and attended meetings in St. Louis (November 14-15, 2006) and Minneapolis (May 9-10, 2007). The principal investigator also joined IEC TC57 / WG14 [1] and attended meetings in Montreal (September 17-20, 2006) and Minneapolis (May 7-8, 1007). These collaborations put EnerNex in an important and unique role for harmonizing the IEC and MultiSpeak efforts.

7 References

Technical papers and web sites referenced in this report include:

1. CIM User Site [Online]. Available: http://www.cimusers.org
2. MultiSpeak [Online]. Available: http://www.multispeak.org
3. X. Wang, N. N. Schulz, and S. Neumann, "CIM Extensions to Electrical Distribution and CIM XML for the IEEE Radial Test Feeders," IEEE Trans. Power Systems, vol. 18, no. 3, pp. 1021-1028, Aug. 2003.
4. T. E. McDermott, "Development of Tools and Resources to Assess the Impact of Wind Generation on Utility Distribution Systems", APPA Engineering & Operations Conference, April 15-18, 2007, Atlanta, GA.
5. T. M. Smith, B. A. Muschlitz, F. R. Goodman, T. E. McDermott, "Advanced Feeder Design for Distributed Generation", IEEE / PES 2007 General Meeting Proceedings, June 24-28, 2007, Tampa, FL.
6. SourceForge project [Online]. Available: http://sourceforge.net/projects/NexPower
7. T. E. McDermott, "Distribution System Data Exchanges to Support Line and Cable Parameter Calculations", IEEE / PES 2007 General Meeting Proceedings, June 24-28, 2007, Tampa, FL.
8. T. E. McDermott, "Open Source Data Translation for Distribution System and Transient Modeling", IEEE / PES 2008 T & D Conference Proceedings, April 20-23, 2008, Chicago, IL (to appear).
9. E. W. Gunther and M. F. McGranaghan, "A PC-Based Simulation Program for Power System Harmonic Analysis", 2nd International Conference on Harmonics in Power Systems, October 1986, pp. 175-183.
10. T. E. McDermott, "Radial Distribution Feeder and Induction Machine Test Cases – Steady State Solutions", IEEE / PES 2006 General Meeting Proceedings, June 18-22, 2006, Montreal, Canada.

Information on various grid modernization initiatives may be found at:

- http://www.themoderngrid.org/ - The NETL Modern Grid Initiative
- http://www.epri.com/intelligrid/ - EPRI IntelliGrid
- http://www.galvinpower.com/ - The Galvin Initiative
- http://www.gridwiseac.org/ - GridWise Architecture Council
- http://www.gridwise.org/ - The GridWise Alliance
- http://www.gridapp.org/ - Advanced Grid Applications Consortium
- http://certs.lbl.gov/ - Consortium for Electric Reliability Technology Solutions
- http://www.openami.org/ - OpenAMI Working Group
- http://www.utilityami.org/ - UtilityAMI Working Group